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ABSTRACT

The National Assessment of Educational Progress (NAEP), the Nation's Report Card, has developed and pilot-tested a variety of hands-on science and mathematics tasks. These tasks were developed as prototypes for use in future national assessments, but the concepts measured and the innovative approaches used are equally suitable for classroom learning. This manual is designed for use by science and mathematics coordinators and teachers to share these techniques. To develop these hands-on activities, NAEP invited the views of science and mathematics educators and worked closely with members of the United Kingdom's Assessment of Performance Unit at Kings College, London University. Tasks were administered as group activities, station activities, and as complete experiments. About 1,000 third-, seventh-, and eleventh-grade students from 12 school districts across four regions of the country were assessed, with approximately 100-300 responses obtained for each task. Results showed that students responded to the tasks, and results conformed to expectations about basic developmental trends in thinking skills. In response to the pilot study, 11 tasks field-tested by NAEP were selected to show a range of possibilities for classroom and assessment use. Each task is presented by thinking skills necessary for successful student performance and the administration mode used by NAEP. Hierarchically arranged tasks are divided into the following sections: (1) classifying; (2) observing and making inferences; (3) formulating hypotheses; (4) interpreting data; (5) designing an experiment, and (6) conducting a complete experiment. The presentation for each task includes a brief explanation of the activity, the student response sheet, a list of the equipment used, and one or more exemplary student responses. (LMO)

Learning by Doing

A Manual for Teaching and Assessing
Higher-Order Thinking
in Science and Mathematics

May 1987
Report No: 17-HOS-80

From NAEP's Pilot Study of Higher-Order Thinking Skills Assessment Techniques in Science and Mathematics, supported by the National Science Foundation through a grant to the Center for Statistics, Office for Educational Research and Improvement, U.S. Department of Education.

The National Assessment of Educational Progress, *The Nation's Report Card,* is funded by the Office for Educational Research and Improvement under a grant to Educational Testing Service. National Assessment is an educational research project mandated by Congress to collect data over time on the performance of young Americans in various learning areas. It makes available information on assessment procedures to state and local education agencies.

The work on which this publication is based was supported by the National Science Foundation through the Office for Educational Research and Improvement under Grant No. NIE-G-84-2006-P4. It does not necessarily reflect the views of either of these agencies.

The ideas for the majority of the exercises for the project were taken from questions constructed for the national monitoring of science performance carried out by the Assessment of Performance Unit (A.P.U.) in the United Kingdom. We acknowledge the cooperation of the United Kingdom Department of Education and Science and of the unit in the Centre for Educational Studies in King's College, London, in making these questions available. However, the questions have been substantially changed to function within NAEP's very different framework. The U.K. A.P.U. is not responsible for the use NAEP has made of its ideas.

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Introduction

Learning by Doing: A Manual for Teaching and Assessing *Higher-Order Thinking* in Mathematics and Science

This manual is designed for use by science and mathematics coordinators and teachers.

Why Hands-on Assessment?

Improving ways to teach and measure higher-order thinking skills has become a national priority, primarily because *A Nation at Risk* and other prestigious reports have identified a crucial need for more sophisticated skills among our nation's students. For example, *Educating Americans for the 21st Century*, the report of the National Science Board's Commission on Precollege Education in Mathematics, Science and Technology, stated, "We must return to the basics, but the basics of the 21st century are not only reading, writing, and arithmetic. They include communication and higher problem-solving skills, and scientific and technological literacy—the *thinking* tools that allow us to understand the technological world around us. These new basics are needed by *all* students. . . ."

The emergence of new jobs requiring technological skills and expertise, concern about the world environment, and the need in our daily lives to make important decisions based on new medical and scientific discoveries have also served to heighten interest in science and mathematics education. Although all schools require some mathematics, student participation in science courses is not widespread in American schools. This is particularly true in elementary schools, where, according to the Association for Supervision and Curriculum Development, a typical fourth-grade curriculum allots only 28 minutes per day to science. Preliminary data from NAEP's 1986 science assessment show nearly one-fourth of the third graders reported that they rarely or never had science class. Even in the higher grades, students did not report taking a variety of science courses. While many eleventh graders reported having taken biology, less than 40 percent had taken chemistry and only about 10 percent had taken physics.

This relatively low participation in science courses suggests that many students may have limited experience with laboratory or hands-on applications of scientific and mathematical concepts. Students should have both the concepts and process skills necessary to organize and carry out projects in an increasingly complex world. Hands-on instructional activities give them the opportunity to use knowledge and skills to solve problems and find out how and why things happen. Further, it is critical that assessment procedures be consistent with the best of these instructional practices. In *First Lessons,* U.S. Secretary of Education William J. Bennett writes:

> "The problem of assessment also constrains the spread of 'hands-on' science. It is relatively easy to test children's knowledge when they have been asked to memorize lists of data for a test. It is much harder to design tests that measure learning derived from direct experience; some school systems provide checklists of students' ability to perform experimental tasks. The challenge before science educators is to develop better means of measuring both factual knowledge and the kinds of understanding students acquire through activities. When that task is accomplished, a major roadblock to science achievement will have been removed."

NAEP, the Nation's Report Card, has developed and pilot-tested a variety of hands-on science and mathematics tasks. These tasks were developed as prototypes for use in future national assessments, but the concepts measured and the innovative approaches used are equally suitable for classroom learning. This manual is designed to share these techniques.

What are the tasks like?

The tasks presented in the following pages require students to think independently about a variety of relationships in mathematics and science. At the first level of the hierarchy, students are asked to **classify** and **sort** by identifying common characteristics of plants and animals. At the next level, students are given materials, equipment, and/or apparatus that exemplify particular mathematical or scientific phenomena or relationships and are asked to **observe, infer,** and **formulate hypotheses.** Another set of tasks is designed to measure students' ability to **detect patterns** in data and **interpret the results.** At the most complex level, students are asked to **design and conduct complete experiments.**

How were the tasks developed?

To develop hands-on activities asking students to solve problems, conduct investigations, and respond to questions using materials and equipment, NAEP invited the views of many science and mathematics educators. NAEP also worked closely with members of the United Kingdom's Assessment of Performance Unit and their science-monitoring staff at Kings College, London University. Many of the tasks were adapted from those used successfully in England, Wales, and Northern Ireland.

How were the tasks administered?

Because a major goal of this pilot project was to judge the feasibility of more innovative and complex assessment procedures, NAEP developed prototypes of different administration formats, including paper/pencil tasks, demonstrations, computer-administered tasks, hands-on tasks, and various combinations of these formats. These were grouped into three major administration modes.

1. *Group activities* were administered to intact classes. These tasks asked for open-ended paper/pencil responses to problems posed in various ways. One task included a demonstration of an experiment by the exercise administrator. The remaining tasks were based on various types of written or tabular information.

2. *Station activities* were hands-on tasks that required students to use equipment or materials to investigate relationships and then answer open-ended questions based on their findings. These activities were divided into two sets of six tasks for each grade level. Groups of six students were given the tasks, with students rotating from activity to activity every eight minutes. One task in each of the sets was administered by computer. Students received directions and recorded their answers by using the computer.

3. *Complete experiments* were administered to individual students. The administrator posed the questions, explained the equipment, and used a checklist to record how students used the equipment to conduct their experiments. After students had completed their investigations, they discussed their findings with the administrator.

Who participated in the pilot testing?

Twelve school districts across the four regions of the country participated in the pilot project. Within each region NAEP selected schools in middle-income urban, disadvantaged-urban, and small-city areas. Twenty-two trained administrators assigned in teams of three conducted the pilot study during April 1986. About 1,000 third-, seventh-, and eleventh-grade students were assessed, with approximately 100-300 responses obtained for each task.

What did the results show?

NAEP collected the pilot data primarily to assess the quality and grade-level appropriateness of the tasks rather than levels of student performance. From this perspective, the findings served their purpose. They indicated that students responded to the tasks, and in some cases, did quite well. Also, the results conformed to expectations about basic developmental trends in thinking skills. For example, improved levels of performance were observed across all three grade levels, and—given the grade-appropriateness of the tasks—students had less difficulty with the sorting and classifying tasks than with determining relationships and conducting reliable experiments.

However, staff and consultants wanted to know much more. The promise of new information obtainable from a hands-on national assessment was perhaps the source of most enthusiasm. Questions abounded: How does performance vary according to students' backgrounds? Are there particular patterns of success across tasks? What problem-solving approaches do students use and how do those affect performance?

What did NAEP learn?

Although managing equipment and training administrators requires ingenuity and painstaking effort, conducting hands-on assessment is feasible and extremely worthwhile. The school administrators, teachers, students, and consultants were all very enthusiastic. The students found the materials engaging, and the school staff and consultants were more than supportive in encouraging further use of these kinds of tasks in both instruction and assessment.

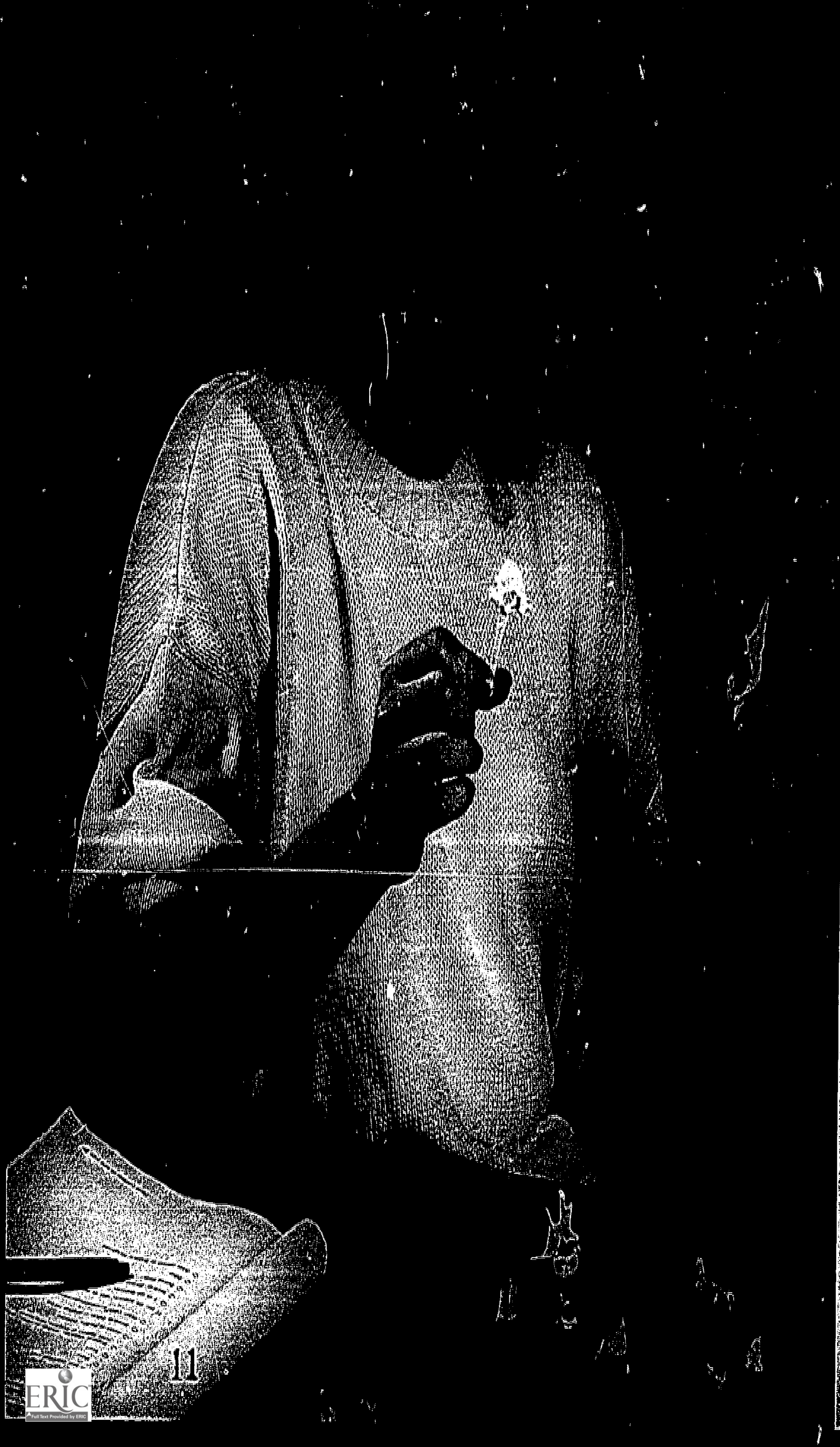
Many educators hope for systematic changes that will enable more hands-on teaching in science and mathematics classrooms. Teachers need the political, financial, and administrative support that will allow them to concentrate on developing ideas and building up the process skills necessary for students to learn to solve problems and accomplish complex tasks.

Why this manual?

In response to the interest and enthusiasm shown in the pilot study, *Learning by Doing* presents 11 tasks field-tested by NAEP. These were selected to show a range of possibilities for both classroom and assessment use. Many of the ideas underlying the hands-on tasks can be adapted to a variety of different science and mathematics concepts. In addition, such procedures as teacher demonstrations using apparatus, paper/pencil applications of some aspects of thinking tasks and computer simulations can be integrated with hands-on experiences to ease the burden of managing students and equipment.

Each of the following illustrative tasks is identified by the thinking skills necessary for successful student performance and the administration mode used by NAEP. The presentation for each task includes a brief explanation of the activity, the student response sheet, a list of the equipment used, and one or more exemplary student responses.

Learning by Doing is adapted from *A Pilot Study of Higher-Order Thinking Skills Assessment Techniques in Science and Mathematics, Final Report*. This two-volume, 537-page report, which describes NAEP's project in detail and presents all 30 tasks included in the pilot study—six group activities, 20 station activities, and four complete experiments—is available from NAEP, CN 6710, Princeton, NJ 08541-6710 for $35.00 plus shipping and handling.



Vertebrae

Station Activity, Grades 7 and 11

Students are asked to sort a collection of small-animal vertebrae into three groups and explain how the bones in those groupings are alike. To complete this task, students need to make careful observations about the similarities and differences among the bones and to choose their categories according to sets of common characteristics.

Classifying tasks can be developed using a wide variety of objects or pictures of objects including seeds, leaves, shells, birds, fish, and flowers.

Vertebrae shows that tasks requiring classification need not be confined to younger students. Indeed, Vertebrae presented a challenge to older students, with sophisticated materials that required them to distinguish among detailed characteristics when they formed their groups.

Equipment Required

Eleven bones labelled A-L as follows:

A = Lumbar dog
B = Cervical rabbit
C = Thoracic dog
D = Thoracic cat
E = Lumbar dog
F = Atlas dog
G = Cervical rabbit
H = Cervical dog
J = Lumbar rabbit
K = Thoracic rabbit
L = Lumbar rabbit

The question with successful responses

WHAT IS THE SAME ABOUT THE BONES IN EACH GROUP?

Here's what you do:

1) Look at the collection of labelled bones. These bones are from the backbones of different animals.

Activities to Conduct

2) Put the bones into three groups. Make sure that there is something the same about all the bones in each group. You must use all the bones.

What did you find:

Record Findings

3) Write the letters of the bones in your three groups.

Group A: C, D, K

Group B: A, E, J, L

Group C: B, F, G, H

4) What is the same about the bones in each of your three groups?

Account for Findings

Group A: all have one long piece projecting; all have a hole in middle of central part

Group B: all have a central large area with hole and two long pieces projecting out

Group C: all are essentially a central structure with a hole in the middle and no long thin pieces projecting off them

(Grade 11) ▶

Wig-Wag

Station Activity, Grades 3 and 7

Students compare the weights of each of four blocks and observe how each individual block affects the movement of the Wig-Wag apparatus. The students then are asked to describe the relationship between the weight of each block and how the apparatus moves. To complete this task successfully, students need to carefully observe how each of the blocks affects the motion of the Wig-Wag, integrate these findings, and make generalizations about the relationship between weight and rate of movement.

Equipment Required

- One inertia balance
- Two large C-clamps
- One block of lead labelled A
- One block of aluminum labelled B
- One block of wood labelled C
- One block of balsa wood labelled D
- A pan scale
- A timer
- Graph paper

Observing and Making Inferences

The question with two successful student responses to part 4

HOW DOES THE WIG-WAG MOVE WITH THE DIFFERENT BLOCKS IN THE TRAY?

This is the Wig-Wag. Push the end of the tray sideways a bit and then let go. Do you see what happens? This is the reason we call it a Wig-Wag.

Here's what you do:

1) Look at the blocks labelled A, B, C, and D.

Activities to Conduct — 2) Lift each block one at a time. What do you notice about the blocks?

Record Findings

Activities to Conduct — 3) Put one of the four blocks in the tray and move the Wig-Wag. Notice how the Wig-Wag moves. Now try with the other blocks.

Explain what you found:

4) Describe the relationship between the weight of the blocks and how the Wig-Wag moves.

Record and Account for Findings — when the havyer block are in the wig wag it moves slower than when the lighter ones are in it

(Grade 3) ▲

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This is the Wig-Wag. Push the end of the tray sideways a bit and then let go. Do you see what happens? This is the reason we call it a Wig-Wag.

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Record Findings

Activities to Conduct — 3) Put one of the four blocks in the tray and move the Wig-Wag. Notice how the Wig-Wag moves. Now try with the other blocks.

Explain what you found:

4) Describe the relationship between the weight of the blocks and how the Wig-Wag moves.

Record and Account for Findings — The heavier the block, the longer it takes to go back and forth.

(Grade 7) ▶

The question with two successful student responses

Watch as the teacher does the experiment.

Watch the Whirlybird arm carefully each time until it stops.

Observe Demonstration

(1) The ball bearings were put in the two outside holes. The Whirlybird arm was wound up exactly three times and let go.

(2) The ball bearings were put in the next two holes. The arm was wound up exactly three times and let go.

(3) The ball bearings were put in the next two holes. The arm was wound up exactly three times and let go.

WHAT WAS DIFFERENT ABOUT THE WAY THE WHIRLYBIRD ARM MOVED WHEN THE STEEL BALLS WERE IN THE DIFFERENT HOLES?

(A) Use this space to jot down notes about what you see happen when the steel balls are moved to different holes.

(B) Use this space to write down your answer to the question in the box.

Record Findings

The closeser they are to the middle the faster it goes.

(Grade 3) ▲

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(1) The ball bearings were put in the two outside holes. The Whirlybird arm was wound up exactly three times and let go.

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WAS DIFFERENT ABOUT THE WAY THE WHIRLYBIRD ARM MOVED WHEN THE STEEL BALLS WERE IN THE DIFFERENT HOLES?

(A) Use this space to jot down notes about what you see happen when the steel balls are moved to different holes.

(B) Use this space to write down your answer to the question in the box.

When the balls were on the outside the whirlybird moved slower than when they were on the inside

(Grade 7) ▶

Conductivity

Station Activity, Grade 11

Students identify each of five identically sealed objects by connecting the boxes that encase them, one by one, to an electric circuit. The students need to make careful observations and interpretations of what occurs as each sealed box is tested. Some knowledge of electric circuits and the conductivity of different materials is needed for this exercise.

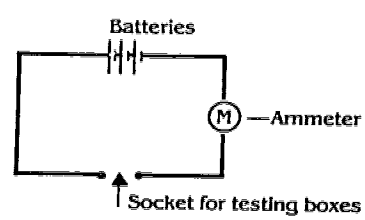
Equipment Required

Five sealed black boxes labelled A-E containing the following materials:

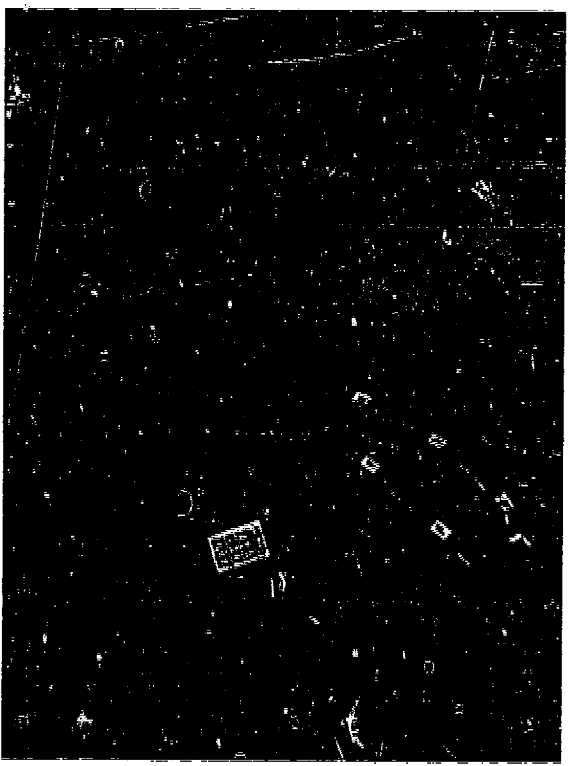
A = a piece of copper wire
B = a resistor
C = a piece of wood
D = a diode
E = a micro relay (variable conductor)

- A circuit set up with three 1.5-volt batteries in holder
- A socket for testing the boxes
- Three spare batteries

Apparatus for the circuit should be set up as shown in the diagram below.



Observing and Making Inferences



The exercise ▶

You have boxes labelled A, B, C, D, and E. Use the circuit to test the boxes.

Activity to Conduct

Determine what each box contains and write down the letter of the box on the blank line. There is one thing listed below that is not in any box. Leave that space blank.

___ 1. A piece of wood?

___ 2. A variable conductor? (Something that controls the rate of current through the circuit)

___ 3. A resistor? (Something that limits the current that can pass through the circuit)

___ 4. A battery?

___ 5. A piece of copper wire?

___ 6. A diode? (Something that only lets the electricity pass through the circuit in one direction)

The question with a successful student response

WHAT HAPPENS WHEN YOU PUT WATER ON THESE THINGS?

Here's what you do:

Activity to Conduct

1) Place a drop of water on each material.

2) Look carefully. What do you see?
Write down what happens to the water on each of the materials.

Record Findings

A) Plastic nothing happens.

B) Painted wood nothing happens.

C) Brick It fades so you can't see it.

D) Metal The drop become a circle.

E) Roof shingle It fades so you can't see it.

F) Glass It stays the same.

3) Now use your magnifying glass and look at each material very closely.

4) Look at the material in the plastic bag very closely.
Do not open the bag.

5) Write down what you think would happen if you put a drop of water on the material in the bag.

Formulate Hypothesis

it would soak throuh

Explain:

6) Write down why you think this will happen.

Account for Hypothesis

Beause It soaked throuh the Brick and Roof shingle and it is made of the same Specimens.

(Grade 3)

Double Staircase

Station Activity, Grades 7 and 11

Students are given a permanently assembled double staircase four blocks high and some loose blocks. Students first determine how many blocks are in the given staircase and then apply numerical reasoning to figure out how many blocks would be needed to build similar staircases six and 10 blocks high. Finally, students are asked to determine the mathematical relationship between a staircase of any given height and the number of blocks needed to build it.

Equipment Required

- Double staircase of wooden blocks that is 4 blocks high and glued to a base
- 24 loose wooden blocks that are identical to those used in the staircase
- Graph paper
- A pencil

Note: The 24 loose blocks permit a student to extend the staircase to six blocks high, but are not enough to build a staircase ten blocks high.

The question with a successful response to part 5

HOW MANY BLOCKS ARE IN THE DOUBLE STAIRCASE?

Here's what you do:

Activity to Conduct	1) Look at the double staircase of blocks.
Record Findings	2) The staircase is 4 blocks high. How many blocks are in the staircase? ________
	3) How many blocks would be in a similar staircase 6 blocks high? How did you figure out your answer? ________
Formulate Hypothesis	________
	4) How many blocks would you need to build a similar staircase 10 blocks high? How did you figure out your answer? ________
	5) What is the relationship between a similar staircase of any height and the number of blocks needed to build it?
Formulate Generalized Hypothesis	It is the # of stairs times itself = the # of blocks.

(Grade 7) ▶

Triathlon

Group Activity, Grades 3, 7, and 11

Students are required by this paper and pencil task to evaluate the results of five children in three athletic events (i.e., frisbee toss, weight lift, and 50-yard dash) and decide which of the five children would be the all-around winner. Students need to devise their own approach for reviewing and interpreting the data, apply it, and explain why they selected a particular "winner." Students also need to be careful in their interpretation because lower scores in the 50-yard dash are better than higher scores, while the converse is true in the frisbee toss and weight lift.

The question with successful student responses

Joe, Sarah, José, Zabi, and Kim decided to hold their own Olympics after watching the Olympics on TV. They needed to decide what events to have at their Olympics. Joe and José wanted a weight lift and a frisbee toss event. Sarah, Zabi, and Kim thought running a race would be fun. The children decided to have all three events. They also decided to make each event of the same importance.

after school they held their Olympics. The children's parents were :s and kept the children's scores on each of the events.

lren's scores for each of the events are listed below:

's Name	Frisbee Toss	Weight Lift	50-Yard Dash
e	40 yards	205 pounds	9.5 seconds
sé	30 yards	170 pounds	8.0 seconds
m	45 yards	130 pounds	9.0 seconds
rah	28 yards	120 pounds	7.6 seconds
bi	48 yards	140 pounds	8.3 seconds

(A) Who would be the all-around winner?

Zabi

(B) Explain how you decided who would be the all-around winner. Be sure to show all your work.

for

I numbered each event from 1-5 - the best score is 5. The worst is 1. Then I added the three scores for each of the children. Zabi's score is 11, which is the highest.

Joe, Sarah, José, Zabi, and Kim decided to hold their own Olympics after watching the Olympics on TV. They needed to decide what events to have at their Olympics. Joe and José wanted a weight lift and a frisbee toss event. Sarah, Zabi, and Kim thought running a race would be fun. The children decided to have all three events. They also decided to make each event of the same importance.

One day after school they held their Olympics. The children's parents were the judges and kept the children's scores on each of the events.

The children's scores for each of the events are listed below:

Child's Name	Frisbee Toss	Weight Lift	50-Yard Dash
Joe	40 yards	205 pounds	9.5 seconds
José	30 yards	170 pounds	8.0 seconds
Kim	45 yards	130 pounds	9.0 seconds
Sarah	28 yards	120 pounds	7.6 seconds
Zabi	48 yards	140 pounds	8.3 seconds

Record Findings

(A) Who would be the all-around winner?

ZABI

(B) Explain how you decided who would be the all-around winner. Be sure to show all your work.

Account for Findings

I wrote in order, all the scores from first place, to fifth place. Then I added them up, whoever had the least amount, won.

◄ *(Grade 7)*

▲ *(Grade 11)*

Heart Rate and Exercise

Grade 11

The experiment with a successful student response

Usually your heart beats regularly at a normal rate when you are at rest. Suppose someone asks you the following questions: Does your heart rate go up or down when you exercise? How much does your heart rate change when you exercise? How long does the effect last?

Think about what you would do to find answers to the questions above. What type of experiment would you design to answer the questions? Assume that you have the following equipment available to use: an instrument to measure your heart rate (such as a pulse meter), a stop watch, and some graph paper.

Briefly describe how you might go about finding answers to these questions.

Describe Experiment

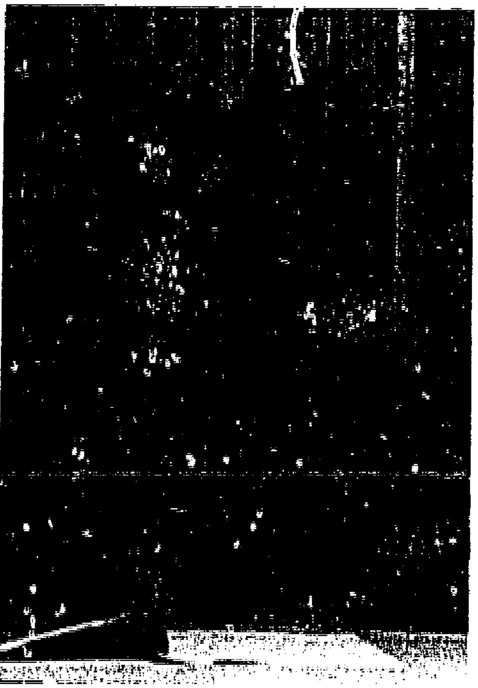
First measure my heart beat after
sitting for an hour or more. Then begin
some kind of exercise (running, jumping jacks)
for about 10 minutes. During this exercise
check every 2min. to see a change in
pulse. The stop exercising and relax while
periodically checking the pulse every 2min after.
Take these results and put them
on a graph. Then use that to observe
changes in pulse rate. This graph can tell
you where the greatest increases and
decreases are during the 1 hour period.

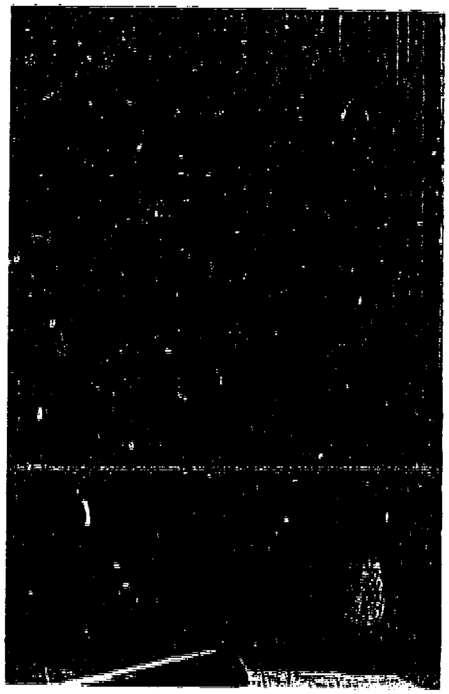
A (Gde 11)

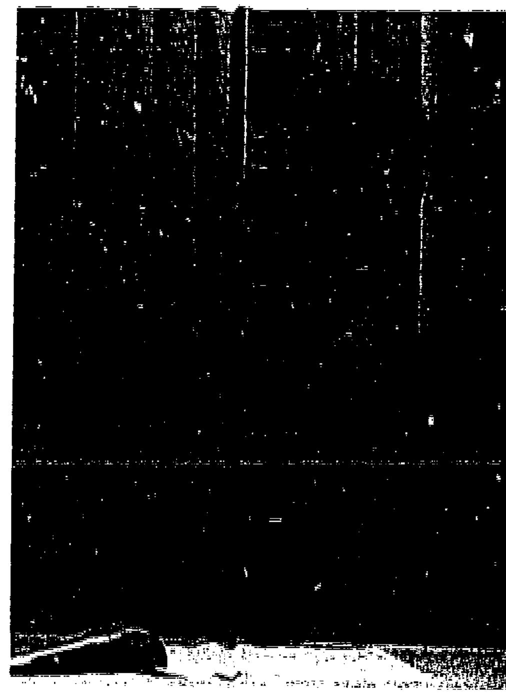
Students design a reliable experiment to determine the effects of exercise on heart rate. In designing this experiment, students need to identify the variables to be manipulated, specify what needs to be measured, and describe how the measurements should be made to provide reliable results. This exercise is included as a prototype technique to assess students' understanding and planning of scientific investigations when actual experimentation in a classroom or assessment setting is difficult.

Designing an Experiment

Identifying Variables, Formulating Hypotheses, and Specifying Measurements







Sugar Cubes

Complete Experiment, Grade 3

Students are given laboratory equipment and asked to determine which type of sugar, granulated or cubed, dissolves faster when placed in warm water that is stirred and not stirred, respectively. To complete this investigation, students need to identify the variables to be manipulated, controlled, and measured. They also need to make reliable and accurate measurements, record their findings, and draw conclusions.

Equipment Required

- Six small glass beakers
- Sugar cubes in packet
- Six packages of granulated sugar, each containing the same mass of sugar as in one cube
- Hot water in thermos (50°C-60°C)
- Two stirrers
- A timer
- A graduated beaker
- A measuring cup
- A graduated cylinder
- A small ruler
- Paper towels
- Paper
- A pencil

Conducting a Complete Experiment

Identifying Variables, Formulating Hypotheses, Taking Measurements, Interpreting Data, and Drawing Conclusions

NAEP administrators used prepared scripts to present complete experiments to individual students. Most of the scripts contained brief background information on the problem, the problem itself, and an explanation of the equipment available to investigate it. As each student worked, her or his activities were recorded by the administrator on a detailed checklist covering students' approaches to the problem, including how they set up the experiment, manipulated the variables, and measured the outcome. The administrator encouraged students to make notes and record findings on a response sheet.

The Observation

Using detailed checklists, NAEP administrators recorded students' strategies for determining—with accurate and reliable measurements—whether loose sugar or sugar cubes dissolved at a faster rate. Successful strategies included:

- testing both types of sugar; and
- testing each by stirring and not stirring; and
- maintaining equal and/or consistent rates when stirring; and
- measuring to ensure equal …s of sugar and equal …s of water for each test.

The first question with a successful student response

FIND OUT IF SUGAR CUBES DISSOLVE FASTER THAN LOOSE SUGAR.

A) Use the space below to answer the question in the box.

Record Findings

The loose sugar disolved faster I think because the loose sugar isn't packed tight like the cubes.

The second question with a successful student response

FIND OUT IF STIRRING MAKES ANY DIFFERENCE IN HOW FAST THE SUGAR CUBES AND LOOSE SUGAR DISSOLVE.

B) Use the space below to answer the question in the box.

Record Findings

It makes a diffrence when you stir the Loose suger cause it dissappears faster than the cubes so if you stir the cubes they willmake a tiny diffrence.

▲ *(Grade 3)* ▶

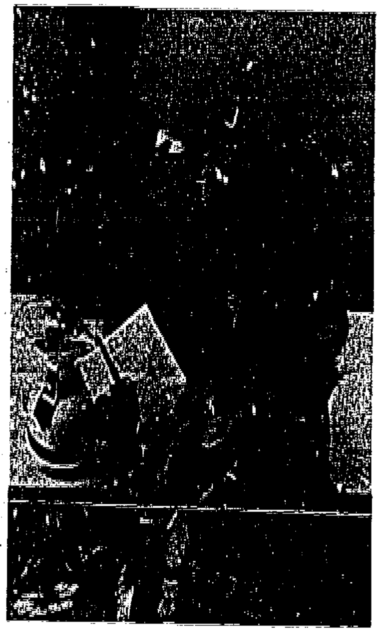
Survival

Complete Experiment, Grades 7 and 11

Students are asked in this simulation task to determine which of two fabrics would keep them warmer on a mountainside on a cold, dry, windy day. As in Sugar Cubes, students need to identify the variables to be manipulated, controlled, and measured. They also need to make accurate and reliable measurements, record their findings, and draw a reasonable conclusion. However, the sophistication and quantity of the equipment call for more extensive procedures and measurements than in the other complete experiments.

Equipment Required

- Five cans labelled A-E
- Two identical aluminum cans A and B
- One plastic can E with the same dimensions as A and B
- One aluminum can C that is the same height as A, B, and E but of a larger diameter
- One aluminum can D with the same diameter as A, B, and E but shorter in height
- A 110°C thermometer
- A stopwatch
- Rubber bands
- Pins
- Transparent tape
- Scissors
- An electric kettle
- Two graduated cylinders
- Sheets of blanket
- Sheets of plastic
- An electric fan
- A small ruler
- Graph paper
- A thermos
- Paper towels
- And pencils



The Observation

Using detailed checklists, NAEP administrators recorded students' strategies for determining which material—blanket or plastic—would keep them warmer in cold, dry, windy weather. Students needed to be particularly careful to test both materials and use the best criteria for determining the better insulator. For example, successful strategies included:

- testing both types of materials by wrapping them around *comparable* cans of the same size, and cans that contain *equal* amounts of water at the *same* temperature;
- taking *baseline* and *final* temperature readings of the water in the cans following a *fixed period* of time OR taking a reading of the time following a *fixed temperature drop.*

As in the other complete experiments, successful investigations included accurate and reliable use of the equipment. In Survival, this would include efficient use of the stopwatch and the thermometer.

The question with a successful student response

WHICH FABRIC WILL KEEP YOU WARMER IN COLD, DRY, WINDY WEATHER?

A) Use the space below to answer the question in the box.

warm body) C - hot water - measured temp. 49°C timed 20 sec
cold body) B - cold water - measured temp. 30°C timed 20 sec
cold body) C - Cold water - covered by plastic - strong wind - 25°C timed 20 sec.
cold body) C - cold water - covered by blanket - strong wind 20°C timed 20 sec.
warm body) A - hot water - covered by plastic - strong winds - 48°C timed 20 sec.
warm body) A - hot water - covered by blanket - strong winds - 44°C timed 20 sec.

27

B) What did you find? Which fabric will keep you warmer?

I found that a warm body's temp. dropped 1°C when covered by plastic and strong winds were present. I also found that when the body temp. is low, being covered by plastic and strong winds being present allowed the temp. to drop 5°C.
When the body is cold, strong winds are present and covered by a blanket the body temp. drops 10°C.
When the body is warm, strong winds are present and covered by a blanket the body temp. only drops 5°C.
I have come to the conclusion from my observations and experiments that plastic will keep you warmer in cold, dry weath

▲ *(Grade 11)*

Density

Complete Experiment, Grades 7 and 11

Students are given a sample of three different materials and an open box. The samples differ in size, shape, and weight. The students are asked to determine whether the box would weigh the most (and the least) if it were completely filled with material A, B, or C. The focus is on which of a variety of possible approaches the student uses to solve the problem. For example, some students might recognize that the solution involves the computation of the densities of the materials. Others may use the weights and volumes of both the materials and the box, or just use the weights of the materials followed by estimations of the amounts of each needed to fill the box.

Equipment Required

- Three different-size blocks (labelled A, B, and C) of different shapes and materials of different densities—a rectangular solid, a cube, and a triangular block that is half a rectangular solid
- a large open box
- a spring scale
- a ruler
- a hand calculator
- paper
- a pencil

The Observation

NAEP administrators used detailed checklists to record each student's procedures and strategies for determining accurately which material would make the filled box weigh the most—and the least. Successful strategies included:

- weighing and measuring the three blocks; computing the volumes of the blocks, and then computing the density of each block without using the box
- weighing and measuring the blocks and measuring the box; computing the volumes of the blocks and the box; computing the number of each that would fit into the box, and then computing its weight filled with each type
- weighing the blocks; estimating carefully the number of each that would fit into the box, and then computing the weight of the box.

The administrator also noted whether the student used units consistently and which measurements, if any, were repeated for accuracy.

The question with a successful student response

WOULD THE BOX WEIGH MOST COMPLETELY FILLED WITH MATERIALS A, OR WITH B, OR WITH C? WITH WHICH WOULD IT WEIGH THE LEAST?

You can use all the things on the table to help you find the answers.

A) Use this space to keep any notes on what you do and what you find out.

Record Findings

A
MATERIAL "A" WEIGHS: 4 oz.
THE BOX WEIGHS - 7½ OZ.
15 boxes of "A" material would fit in the box, so the box Plus 60z of material would weigh 67.5 oz.

B
MATERIAL "B" WEIGHS: 2.2 oz.
50 boxes of "B" material would fit in the box so the box plus 110 oz. of material would weigh 117.5 oz.

B) Fill in the blanks to complete the sentences below:

Record Findings

The box would be heaviest filled with material B

The box would be lightest filled with material C

MATERIAL "C" WEIGHS: 3.5 oz.
14 triangles of "C" material would fit into the box plus 49 oz of material would weigh 56.5 oz.

▲ (Grade 7)

Another successful student response using a different approach

WOULD THE BOX WEIGH MOST COMPLETELY FILLED WITH MATERIALS A, OR WITH B, OR WITH C? WITH WHICH WOULD IT WEIGH THE LEAST?

You can use all the things on the table to help you find the answers.

A) Use this space to keep any notes on what you do and what you find out.

Record Findings

A = 110gr.
B = 65gr.
C = 100gr.

Box = Width = 18 cm
height = 10.25 cm
Length = 40.5 cm
Volume of Box = w(L)(h)
= 7472.25 cc.

A - L 6cm
W = 6cm
H = 6cm
Volume 216 cc

C L = 8cm
W. = 8cm
H = 8cm
Volume 512(½) = 256 cc

B L = 7cm
W. = 3.5cm
H = 4cm
Vol. = 98 cc.

for A = 110gr / 216cc = 3805.31 / 7472.25

for B = 65gr / 98cc = 4956.07 / 7472.25

for C = 100gr / 256cc = 2918.85 / 7472.25

B) Fill in the blanks to complete the sentences below:

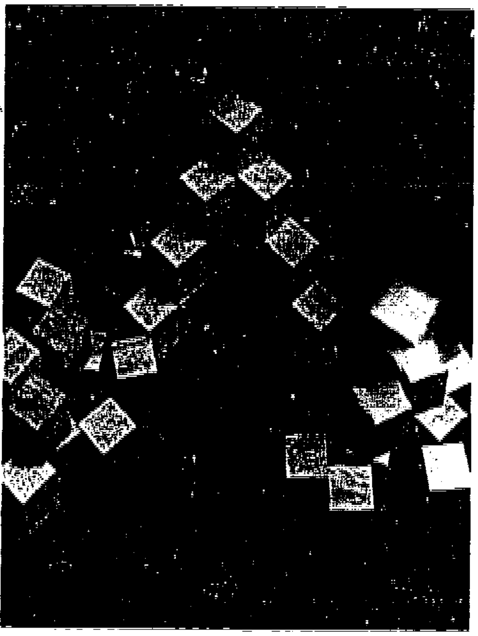
Record Findings

The box would be heaviest filled with material B

The box would be lightest filled with material C

▲ (Grade 11)

Thoughts for the Future



Results from the Second International Science Study show that our nation's students lag behind students in other countries in laboratory and inquiry skills.* Greater attention must be paid in American schools to higher-order thinking skills if we are to produce a citizenry able to meet our future needs. "Hands-on" activities are an excellent way to improve process skills. Students have the opportunity to see how things work, think about relationships, plan investigations, and learn from their successes and failures.

Such activities, however, require time—time for teachers to prepare, time for teachers to work with individual students, and class periods long enough to promote coherent and in-depth study. Additionally, teachers, administrators, and parents must devote the necessary energy and resources to help students achieve these new goals. This will not be easy and will require dedication by all concerned.

Finally, we should recognize that schools teach what is tested. In conjunction with improving science and mathematics curricula, we must provide for both instruction and assessment of higher-order thinking skills. The use of hands-on assessment techniques will guide instruction in more beneficial directions as well as to provide better information about students' understandings of the concepts underlying science and mathematics. Our hope is that the examples included in this manual will facilitate and encourage this process.

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*Jacobsen, W.J. (1987). The current status of the Science Curricula: Insights from the Second International Science Study. In *This Year in School Science 1986: The Science Curriculum*, AAAS, Washington, D.C.

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